Injury Extra (2008) 39, 106–112

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CASE REPORT

Salvage of multiple extensor tendon ruptures using extensor carpi radialis longus tendon in volar-dislocated rheumatoid wrist

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Accepted 30 August 2007

Introduction

Within the past 30 years, no studies describing wrist tendon transfers to digits have appeared in the literature.[3,11] Since those days, experience by experience, surgeons came to know of its usage in the mobile wrist was never clinically successful and transfers to finger extensors were gradually been abandoned. However, we have no other candidates except extensor carpi radialis longus as a power source because arthrodesis had to be performed in the same staged operation.

The plating technique now has been replacing the medullary nail in wrist arthrodesis.[4–6,10] However, we chose intramedullary screwing fixation supported by two additional Kirschner wires, in an attempt to avoid tendon laceration, and succeeded in re-aligning in the wrist to overcome the disadvantages of intramedullary fixation such as back-out. Since the clinical and functional results were unexpectedly good, we would like to describe our surgical method.

Case report

A 67-year-old right-handed rheumatoid woman with anteriorly dislocated bilateral carpal bones visited a hospital to obtain an orthosis for possible reduction or stabilization of her right wrist for pain relief. She had a 10-year history of rheumatoid arthritis with involvement of atlanto-axial joint dislocation as a predominant site of pain and deformity which had required occipito-atlanto-axial fusion 3 years earlier. Her disease was classified as Steinbrocker Stage III-2 or Larsen grade IV. Her medical regimen for one day included salazosulfapyridine 500 mg and predonisolone 10 mg/day, and her disease activity seemed well controlled.

When her right wrist was gradually held in reduction, she felt acute temporary pain in her wrist. Several days after, she still could not actively extend her middle, ring, small fingers, so she visited our hospital for further evaluation and possible treatment. On examination, her bilateral wrists were severely deformed with severe instability, but the finger deformity was not so severe. There was no sensory disturbance, and the pulse in the radial artery was easily detected. She could not actively extend her right middle, ring and little finger (Fig. 1), but could flex them completely. Although the complete Manual Muscle Test was difficult to perform, the muscle strength of her extensor carpi radialis longus (ECRL) and/or brevis seemed preserved (Fig. 2).

On radiological estimation, her wrist showed marked destruction of the wrist disappearing carpus with palmar dislocation and prominent of the ulna (Fig. 3). Under radiological image of the right wrist, the metacarpal bones and the disappearing carpus were easily reducible by manual

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1572-3461
doi:10.1016/j.injury.2007.08.038

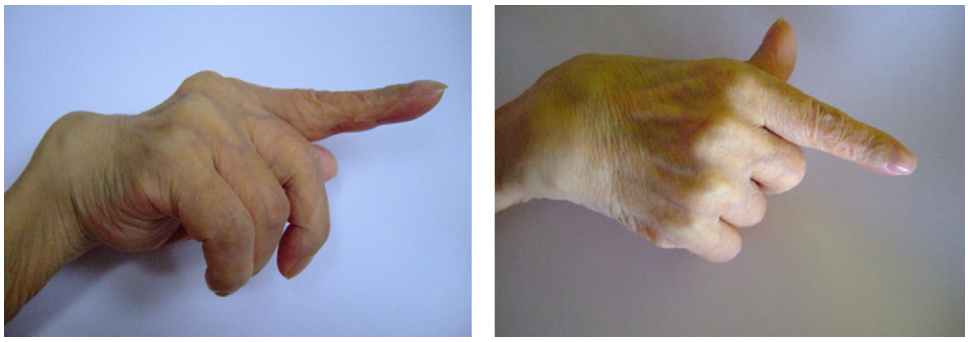

Figure 1 Presurgical photos showing the patient could not actively extend her right middle, ring and little finger.

Figure 2 Presurgical photos show muscle strength of Extensor carpi radialis longus and/or brevis are preserved, although complete Manual Muscle Test was difficult to perform.

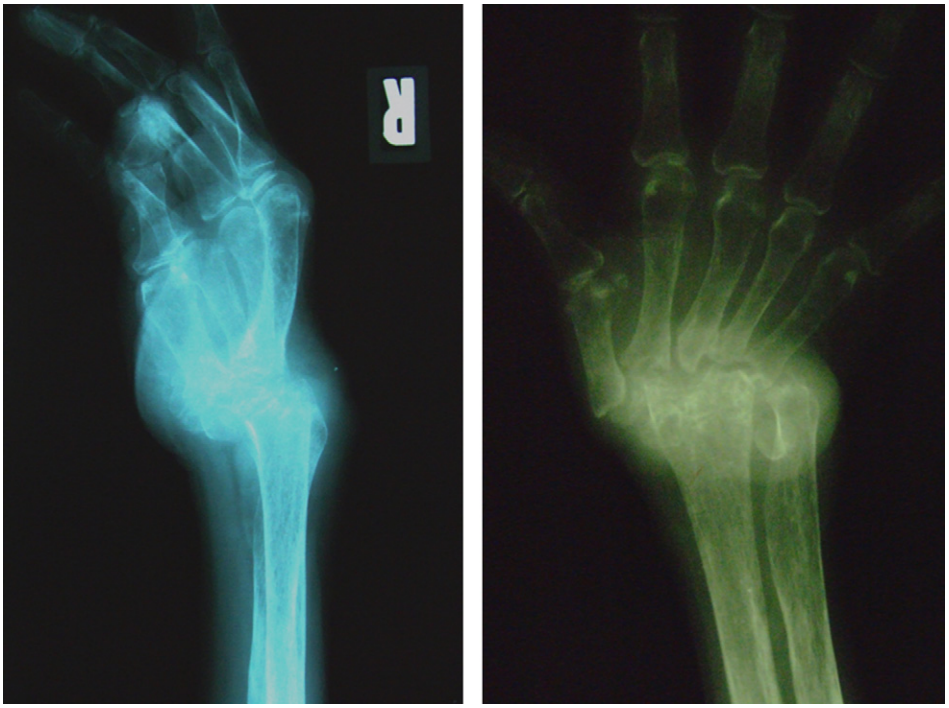

Figure 3 Preoperative X-ray shows marked destruction of the wrist disappearing carpus with palmar dislocation and prominent of the ulna. Under radiological image of the right wrist, the metacarpal bones and the disappearing carpus were easily reducible by manual stress.

stress. Therefore, we did not find it necessary to perform soft tissue release in total wrist arthrodesis.

Operative technique

The patient was placed in the supine position under general anaesthesia with a pneumatic tourniquet. With the right shoulder abducted 90° and her right elbow fully extended.

Tenosynovectomy is performed through a midline dorsal approach to protect the radial sensory and dorsal ulnar sensory nerves. The extensor retinaculum is entered between the fifth and sixth extensor compartments, and a radially based flap of retinaculum is raised to the second dorsal compartment to allow excision of the infiltrating synovium around the extensor tendons.

In observing the Fourth compartment, the distal stumps of extensor digitorum communis (EDC)3, EDC4, EDC5 and extensor digiti mini (EDM) seemed sharply severed and were found diffusely infiltrated by synovium, not so severely attenuated but accompanied with clotting. Their proximal stumps were not exposed in the operation field.

EDC2 and extensor incidis were neither attenuated nor severed, but sparse synovial infiltration was observed, so these tendons were judged inadequate for the tendon transfer.

In observing the second compartment, the ECRL tendon was identified and appeared rather intact as a possible candidate for tendon transfer. It was exposed to its insertion point at the base of the second metacarpal bone and taped for marking.

Entry to the radiaocarpal and midcarpal joint was attempted through a straight longitudinal incision on the ulnar side to make a radially based flap of joint capsule before synovectomy and carpal bones excision. However, the flap was very fragile and easily breakable because of rheumatic inflammation.

Complete surgical resection of the remnant carpal bones was performed by a rongeur or a curette. Although the soft tissue release procedure for reduction was not necessary as the preoperative stress view indicated, the bases of the second to fifth metacarpal bones and distal end of the radius were exposed periosteally to judge the size of the iliac bone graft. The distal end of the radius was osteotomied at the angle of 15° in the sagittal plane and vertically in the coronal plane. The cut-off bone from the radius was later mashed by the rongeur and grafted into the gap.

Tricortical bone measuring 40 mm in length, 25 mm in width and 20 mm in height was harvested from the right iliac crest, and the cancellous bone was also harvested. The recipient site was anointed with bone wax for hemostasis. After irrigation, this site was closed.

In performing the arthrodesis of the right wrist and bone graft, first, a small longitudinal stab skin incision was made on the mid-lateral aspect of the proximal one-third of the second metacarpal bone. A 1.6-mm guide pin was chosen and driven through the stab skin incision, passing through the base of the second metacarpal bone, through the iliac bone graft, then through the cancellous bone of the distal radius and finally penetrated the ulno-volar aspect of the distal radius. Next, a 1.6-mm Kirschner wire was percutaneously introduced from the distal one-third of the lateral aspect of the second metacarpal, and passed through parallel to the first Kirschner wire. The first Kirschner wire was replaced by an Acutrak screw (Acumed LLC, 5885 NW Cornelius Pass Road, Hillsboro, OR 97124) using the same technique as a cannulated screw.

At this point, fixation between the iliac bone graft and radius was inadequate, so further percutaneous fixation by Kirschner wire was added through the radius to the iliac bone graft. Since this final additional Kirschner wire provided good internal fixation, the two Kirschner wires were not replaced by Acutrak screws, given the risk of bone breakage. The bone gap was filled with previously mashed bone chip and harvested cancellous bone.

Because traumatic tendon ruptures of EDC3, EDC4, EDC5 and EDM were found to be on the level of the distal end of the radius with the fingers extended, interlacing sutures of the ECRL to the ruptured EDC3, EDC4, EDC5 and EDM were considered possible. Therefore, the insertion of the ECRL was detached from the base of the second metacarpal bone, pulled out proximally, rerouted and transferred to EDC3, EDC4, EDC5 and EDM, as shown in Fig. 4, so that the tension was adjusted to achieve full grip of fingers with the ECRL maximally stretched.

After irrigation, Penrose drain was cut and placed under the sutured tendon site for possible prevention of tendon adhesion, resembling an open fan.

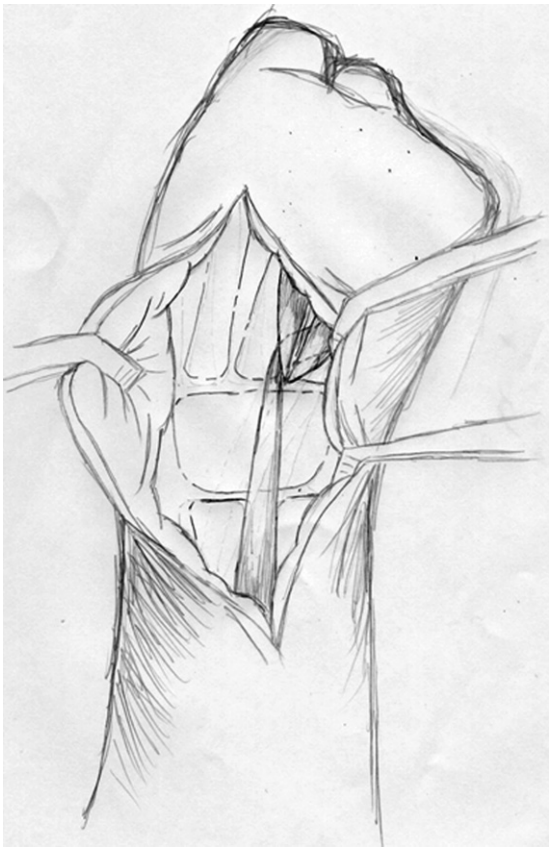

Figure 4 Drawing shows that insertion of the ECRL was detached from the base of the second metacarpal bone, pulled out proximally, rerouted and transferred to EDC3, EDC4, EDC5 and EDM so that the tension was adjusted to achieve full grip of fingers.

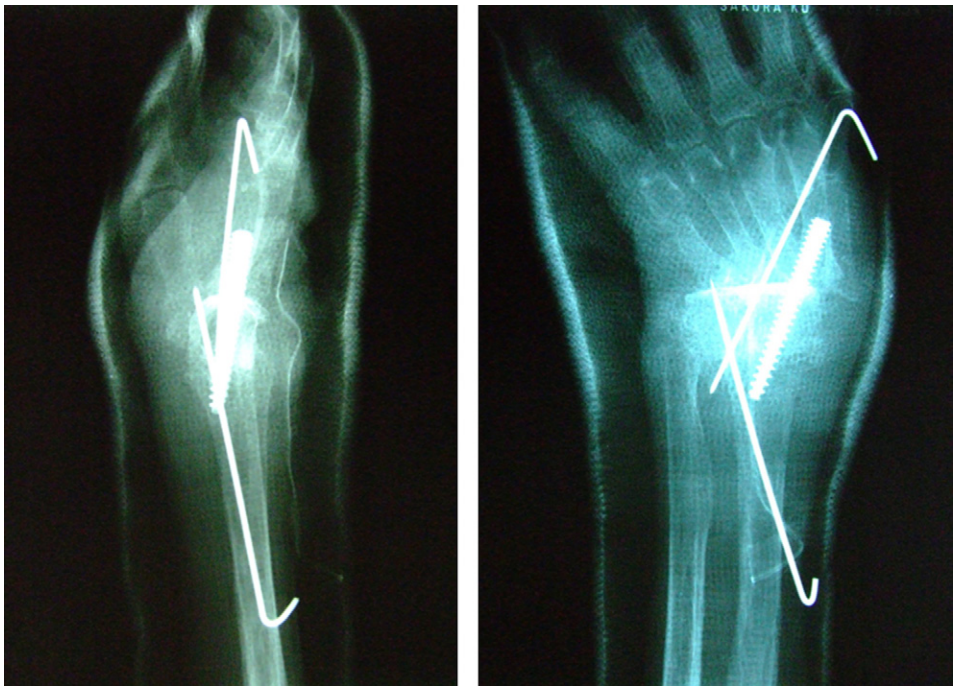

Figure 5 Postoperative X-ray showing good reduction indicating Penrose drain cut open like a fan and placed over bare bone. After operation, right wrist and forearm was immobilized by outrigger-like forearm cast holding the fingers in extension and allowing full active flexion.

After operation, the right wrist and forearm were immobilized by an outrigger-like forearm cast holding the fingers in extension and allowing fully active flexion for 4 weeks (Fig. 5). Active flexion of fingers and passive extension was recommended with this forearm cast. The Penrose drain was removed 7 days postoperatively. The outrigger-like forearm cast was replaced by an outrigger forearm splint 4 weeks postoperatively. The proximally and distally inserted Kirschner wire, were respectively removed 1 and 9 weeks postoperatively.

Bone union was judged to be obtained 3 months postoperatively, and the splint was completely removed.

At this writing six months have passed, and the clinical result is good, as shown in Fig. 6 and Table 1. Fig. 7 shows firm arthrodesis of the right wrist

Table 1 indicates the fingertip-to-palmar-distance for each finger in the follow-up period. According to the Standard Patient Review Questions indicated by Weiss et al.[12], the patient's function was very satisfactory as described below.

The patient is very satisfied because she can do everything that she used to do with the operated hand. She does not wish she had had the fusion surgery earlier, although it had been recommended before the traumatic tendon rupture occurred. However, she told us that the acute tendon ruptures had encouraged her to decide to undergo surgery.

She does not prefer a different position of the fused wrist. It took one month for the right wrist to attain maximum improvement after fusion. She rates her wrist 1 and 7, preoperatively and postoperatively, respectively, and she looks forward to a complete return to housework.

Discussion

Multiple extensor tendon ruptures have several treatment options. If the ruptured tendons were EDM/EDC5/EDC4/EDC3 as in this case, EDC3 side-to-side EDC2 and EIP to EDC4/5 is considered to be standard. As an alternative method, EDC3 side-to-side EDC2 can be taken over by FDS D4 to EDC4/D5.[9]

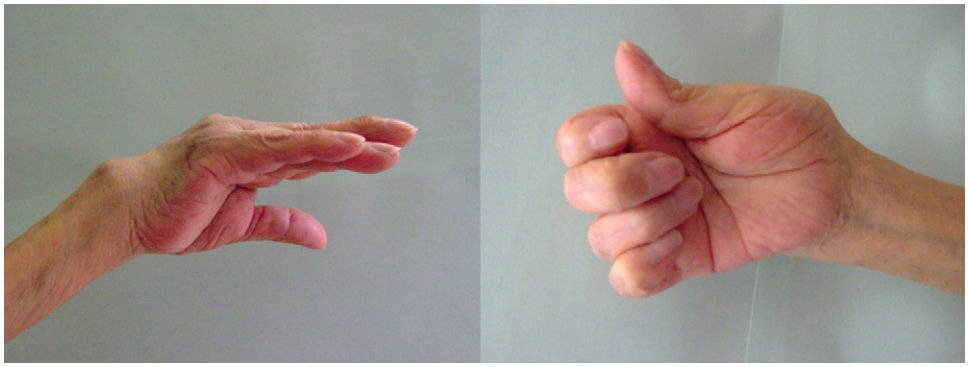

Figure 6 Postoperative photo showing unexpectedly good range of motion, with less extension lag of MP joint.

Table 1 Clinical results of the finger motion

	Preoperatively	Postoperatively	
	Extension lag (°)	Extension lag (°)	Tip to palmar distance (cm)
Index	−35	−30	0
Middle	−135	−30	0.5
Ring	−145	−35	0
Little	−140	−30	0.5

But in the case under study, the common golden standard technique is impractical not only because EDC2 and EIP had been sparsely infiltrated by synovium and seemed to be inadequate to extend the three other fingers but also because these two tendons anatomically responsible for the index seem insufficient as the motor source of four fingers. And, needless to say, transfer of FDS D4 to EDC4/D5 is technically very demanding and unreliable after the arthrodesis with reduction.

Until the end of the 20th century, an intramedullary technique such as a Rush nail was more common in rheumatic wrist arthrodesis.[4] Lee et al. described a wrist arthrodesis technique combined with an intramedullary pin and autogenous iliac crest bone graft in a large bone defect similar to our case.[5] Recently, the plating technique, which allows for more rigid fixation and earlier mobilization which are crucial in RA patients, is becoming the method of choice for its more reliable maintenance of wrist position. Rehac et al. reported high bone union rates and similar rates of complications in both plating group and pin fixation.[10] However, Meads et al. reported hardware removal after plating was necessary in 15% of the cases because of soft tissue problems. This rate is quite high and not acceptable in consideration of tendon reconstruction surgery.[6] Obviously, the benefit of plating is not only the rigid fixation but also the fusing of the wrist in optimal alignment. The possible downside of plating in a tendon transferring technique is irritation of the transferred tendon, especially when the plate is not totally covered with the soft tissue of the sliding floor.

Therefore, we opted for the intramedullary screw fixation technique combined with percutaneous pinning. The Acutrak screw was introduced through the stab skin incision on the mid-lateral aspect of the proximal one-third of the second metacarpal bone where extensor tendons never excurse because of our concern about screw removal, should some trouble occur. In terms of obtaining optimal dorsiflexion in arthrodesis, it was successful as preoperatively planned. Unfortunately, it should have been more neutral, since too much ulnar deviation resulted because the cusp of the Acutrak screw should penetrate the cortical bone of the distal radius.

The concern here is whether or not the ECRL transfer to the extensor tendons which motor three fingers is justified. Use of the wrist extensor tendons was recommended by several authors over the past 50 years.[3,11] Although no clinical results using the wrist extensors were described in the literature, the excursion of the wrist motor is expected less than the finger extensors,[2] and even maximal tendon movements produce incomplete digital motions. But we considered that the choice of the flexor tendons might later provoke skin trouble due to swelling caused by searching and identifying them; and if they do not cause skin necrosis, applying them for power sources is contraindicated because this arthrodesis technique accompanying reduction of volar-dislocated wrist does not provide a safe interosseous membrane for transferred tendon passage. Passing them ulnar or radial to the iliac bone graft is more risky in terms of bone abrasion. Table 2 was redrawn from

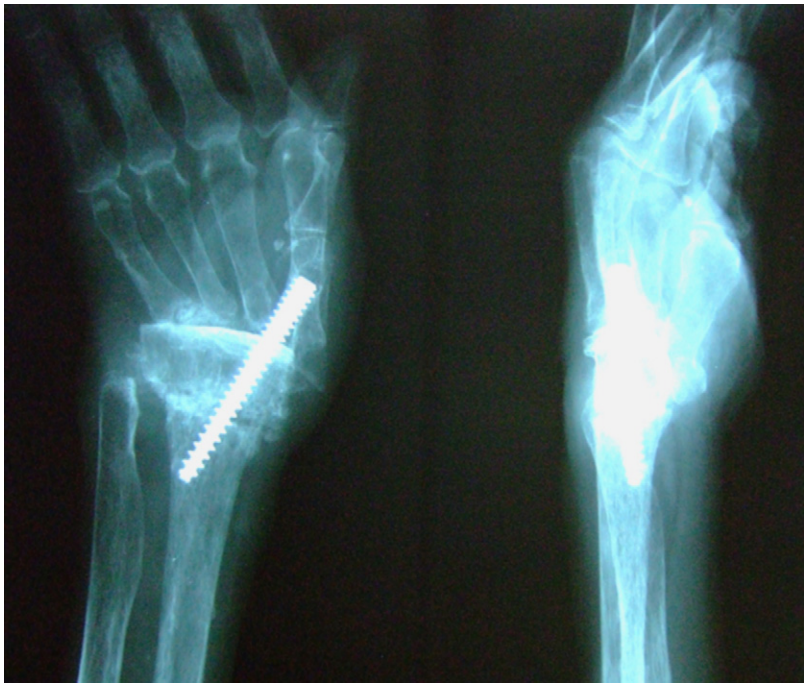

Figure 7 X-ray 5 months after surgery shows firm arthrodesis of the right wrist.

Table 2 Fundamental capability of each tendon for tendon transfer

Tendon	Excursion amplitude (mm)	Absolute muscle power	Need for rerouting	Muscle power decrease	Further surgical intervention
ECRL	33	1.1	No	No	No
FDS	64	4.5	Yes	Yes	Yes
FDP	70	4.5	Yes	Yes	More invasive than above
EDC	50	1.7			

the literature according to Curtis RM.[2] Although the excursion amplitude (64 mm) of the Flexor digitorium sublimis (FDS) is greater than the 33 mm of the wrist extensors, the volar aspect of a finger must be surgically intervened to be pulled out in order to obtain the benefit of selecting one of the finger flexors. Postoperative finger swelling is quite likely to hamper finger motion, or in the worst case, severe contracture, especially in an arthritic hand like this one. In terms of working capacity, considering EDC is responsible for four fingers, Extensor carpi radialis longus could provide a comparable power source for three fingers. If one of the flexors were used in this case, a muscle and its tendon would have to form an acute angle between the origins even were an adequate pulley created. Therefore, efficiency of the flexor would be diminished by friction at the pulley. Thus, in our opinion, ECRL would be the best among the many choices of tendon transfer candidates.

The best prognosis occurs when treating single or double tendon ruptures, with 60—70% of patients obtaining a full range of motion after transfer. As the number of tendon ruptures increases, along with the complexity of the surgical reconstruction, less finger motion can be anticipated.[7,13]

Some surgeons might wonder whether tendon grafting such as the palmaris longus might be a better alternative. We felt it would not be wise to perform a tendon graft which requires two suture sites for each tendon on the iliac bone graft. Bora et al. reported that a tendon graft in a multiple tendon rupture without wrist dislocation[1] provided an average 65° of active motion at the metacarpophalangeal joints. As Fig. 6 illustrates, our case is showed much poorer clinical results. However, our patient is quite satisfied because of wrist pain relief, gaining stability and recovery of active voluntary finger extension. Moreover, the preserved palmar-tip distance is related to her satisfaction,[8] although the postoperative total active range of motion of fingers and extension lag average about 170° and 30° , respectively.

The normal amplitude of the flexor digitorum profundus or FDS can mobilize fingers from complete extension of the distal interphalangeal (DIP) joint and proximal interphalangeal (PIP) joint, and hyperextension of the metacarpophalangeal (MP) joint with the wrist extended to full grip of the fingers with the wrist flexed. In the fusioned wrist, if the atomical diameter of the MP, PIP and DIP are 20, 15 and 10 mm, respectively, and if the required range of motion for each joint is 90°, 100° and 80°, respectively, the necessary amount of excursion of the tendon responsible for mobilizing fingers could be calculated. As the MP, PIP and DIP measured 11, 7 and 6 mm in diameter, respectively, the required amount of excursion was $11 \times 3.14 \times 90/360 + 7 \times 3.14 \times 100/360 + 6 \times 3.14 \times 80/360$ = about 19 mm. Technically speaking, this theoretical required minimal excursion length is quite small compared to the amplitude of the ECRL.

There are two fundamental approaches to determine the tension of the transferred tendon. One is the classical tenodesis test which gives a higher priority to reconstructing extension ability than to preserving flexion ability[3]. The other way is to adjust the tension so as to achieve full grip of fingers with the transferred tendon maximally stretched as in the present case report.

We preoperatively assumed that we could not perform a tenodesis test in the fused wrist, and that the second approach would assure a satisfactory clinical course. Transferring tendon with less amplitude requires suturing in the latter method because patients satisfaction depends on the tip-to-palmar distance, not on full finger extension.

As to the finger motion, clinical results were far better than expected. We surmise that the ECRL is like a power source in the fused wrist where no competitive flexors such as the Flexor carpi radialis can ever contract; it does not act as a wrist extensor at all, but serves only to extend the affected digits, In this way, the contraction power would be efficiently conveyed to allow finger extension. The literature about using the ECRL as a power source of the finger extensors in a preserved wrist joint was quite old and the clinical results were not described[3,11].

We concluded that an intramedullary screwing technique combined with transfer of the extensor carpi radialis to the multiple finger extensor tendon rupture in the rheumatoid case requiring total wrist arthrodesis could be one of the standard therapeutic options if adequate tension of the tendon is achieved for satisfactory flexion.[8]

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